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Appendix IV-06 A Predetermination of Pile Lengths Based on Analysis of Soil Properties

1. APPLICATION:

By inspection of the soil borings, break the subsoil into specific zones or stratums. This can be done individually or as a group, depending upon the horizontal cross-sectional similarity of the material. Utilize the standard penetration test results, soil description, and the laboratory determination of the physical properties of the soil in establishing zones.

Lengths are determined by computing supporting capacity of the zones penetrated. Estimated penetration will be at the elevation which the computed capacity equals the required capacity times a safety factor of three.

Formulas for computing supporting capacity are as follows:

Cohesive Soils

This category covers clays with an apparent angle of internal friction less than 15°. Capacity is primarily a function of the shear strength of the soil which is established from the unconfined compression tests.

$R_f = ½ Q_u Z A_p T \Delta d$ (1)

$R_t = ½ Q_u Y A_t$ (2)

Where:

R_f = Increment of supporting capacity developed through skin friction (lbs)

R_t = Increment of supporting capacity developed through tip resistance (lbs)

Q_u = Confined compressive strength (lbs/sq ft)

Z = Skin friction coefficient (dimensionless)

Y = End bearing coefficient (dimensionless)

A_p = Average surface area of pile (sq ft/ft) of penetration in zone

A_t = Area of pile tip (sq ft)

T = Taper coefficient (dimensionless)

Δd = Embedded length of pile in zone (ft)

Where unconfined compressive strength data is inadequate, use Chart J for estimate of Q_u based on the standard penetration test blow count.

For values of Z, based on the standard penetration test, use Chart A or Chart C. Chart C has Z' values designated for use in the Lake Agassiz Basin Area (Red River Valley). For remainder of the state, use Z values, Chart A.

For values of Y, based on the standard penetration test (N), use Chart B.

The taper coefficient "T" is considered unity in all areas except in Lake Agassiz Basin clays with "N" less than 20. For values of T, based on the amount of pile taper, use Chart D. When using constant cross-sectional area piles, use taper = O or T = 0.6.

Granular Soils

This category covers sands with an angle of internal friction (φ) considered to be between 25° - 45°. Capacity is considered primarily a function of the confining pressures.

$R_f = n\, K_\varphi\, P_d \,\text{Sin}\, A_p\, \Delta d$ (3)

$R_t = N_q\, A_t\, P_D$ (4)

Where:

n = Skin friction coefficient (dimensionless) used for cases where φ (friction angle of soil) differs from (arc tan of coefficient of friction between soil and pile)

K_φ = Factor relating vertical soil pressure to soil pressure acting on pile walls (dimensionless)

P_d = Vertical effective pressure in soil at any depth d (lbs/sq ft)

P_D = Vertical effective pressure in soil at pile tip (lbs/sq ft)

N_q = Factor relating vertical soil pressure to supporting pressure beneath the pile tip

(R_f, R_t, A_p, A_t, and Δd are same as for cohesive soils)

The value of confining pressure P_d for a zone is determined by one or both of the following formulas:

Above Water Table: For examples of determining P_d see pages 56 and 228 of FHWA publication “Soils and Foundations Workshop Manual.”

$P_d = (W_s \times H_s)$

Below Water Table:

$P_d = (W_s - W_s/Sp\ Gr) \times H_s$

Where:

W_s = Dry weight of soil (lbs/cu ft, weight of soil above ground water)

H_s = Height of soil from ground surface to effective depth (ft)

Since P_d is a function of H_s, its value will vary from top to bottom of the zone. If the pile will penetrate the full depth of the granular zone, the effective depth will be at a point one-half the full depth of the zone. For partial embedment in a granular zone, use one-half the embedded depth in that zone. For values of P_D to determine R_t, use effective depth to pile tip.

The friction angle, φ, is considered a function of the standard penetration test below count (N) and the confining pressure (P_d). Values for φ can be obtained by reading vertically upward on Chart E to the applicable P_d curve, then horizontally to Chart F.

For values of K, based on the soil friction angle (φ) and the pile displacement (cu ft/ft), use Chart F.

For values of n, based on the soil friction angle (φ) and sand on pile friction angle ( ), use Chart G.

For values of N_q, based on the soil friction angle (φ), use Chart H.

Cohesive - Granular Soils

This category covers intermediate sand-clay mixtures. Values of actual φ are considered to be between 20° - 25°. This is the most difficult category to analyze. At present, capacity is considered a function of both the confining pressures and the shear strength of the soil zone in question.

$R_f = [(ZC) + (n\ K_\varphi\ P_d\ Sin)]\ A_p\ \ \Delta d$ (5)

$R_t = [(YC) + (N_q\ P_D)]\ A_t$ (6)

Where:

C = Cohesion (lbs/sq ft)

All other terms are as defined under cohesive and granular soils.

For values of cohesion (C), based on the unconfined compression (Q_u), use Chart I.

The sand portion is considered independently when determining values of n, K_φ, P_d, P_D, and N_q. Use same procedure as outlined under granular soils.

For the clay portion, determine values of Y and Z as outlined under clay soils.

2. GENERAL NOTES:

a. Each zone which pile is assumed to penetrate delivers a portion of the total bearing capacity based on the appropriate R_f values determined by application of the formula for that particular zone.

   Tip resistance (R_t) is computed on values obtained from the soil zone which tip is finally embedded. As ΣR_f approaches the required bearing, solve for the applicable tip supporting capacity (R_t) in zone which tip is embedded by use of formulas (2), (4), or (6). For clays, rearrangement of formula (1) to solve for Δd will determine penetration into the lowest embedded zone. For sands and sand-clay mixtures, solution by trial and error is usually the easiest method for determining penetration into the lowest embedded zone.

b. In some cases where piles are embedded in soft silt or clay and obtain most of their bearing capacity by friction, it is necessary that the computation of the safe design load be supplemented by a computation of the ultimate bearing capacity of the entire group.

   As a rule of thumb, this group bearing capacity reduction should be made on piles which have a spacing closer than 4 pile diameters.

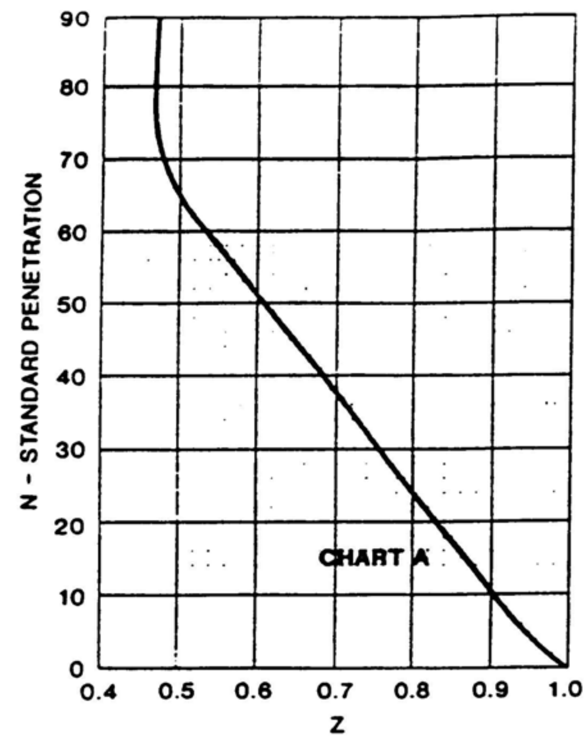
   Formula: Converse-Labarre method as recommended by AASHTO.

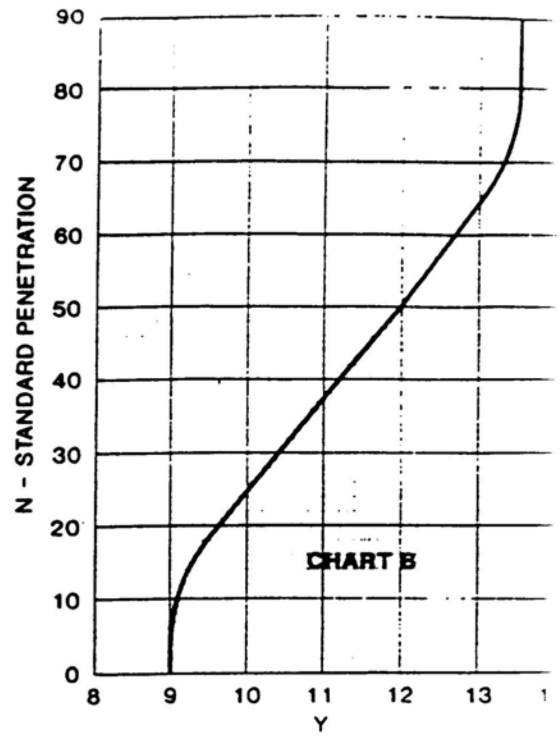
   No reduction due to grouping is computed when piles are end bearing piles. For groups which partake of both actions, only the portion in friction is reduced.

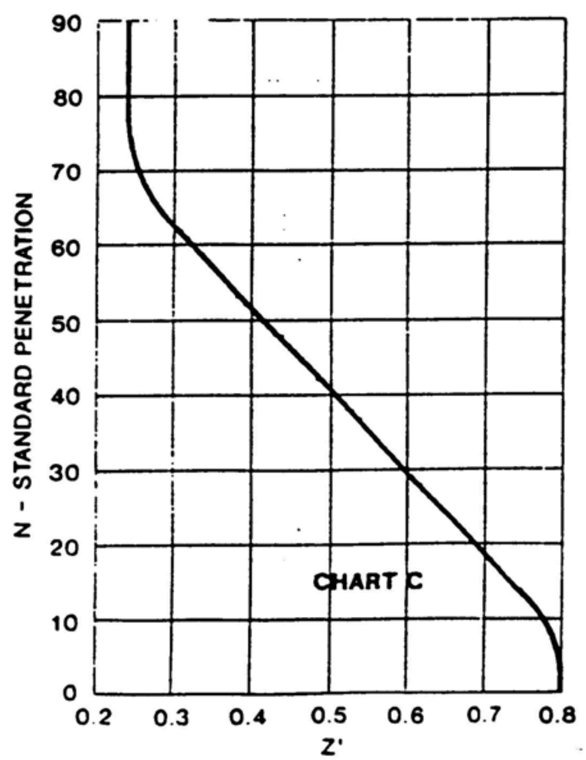
c. When determining the average pile area per foot (A_p) neglect inside flanges and web of H-beam piles and use as a rectangle.

d. Vertical pressures at the pile point while resting on any hard layers of coal or rock is assumed to spread uniformly within a cone (or rectangle) the sides of which are inclined 60° to the horizontal. Safe supporting capacity of any underlying soft material should be analyzed by methods applicable to spread footing design.

e. Negative friction induced by long term settlement of abutment fills overlaying soft cohesive soils should be accounted for when predetermining abutment pile lengths.







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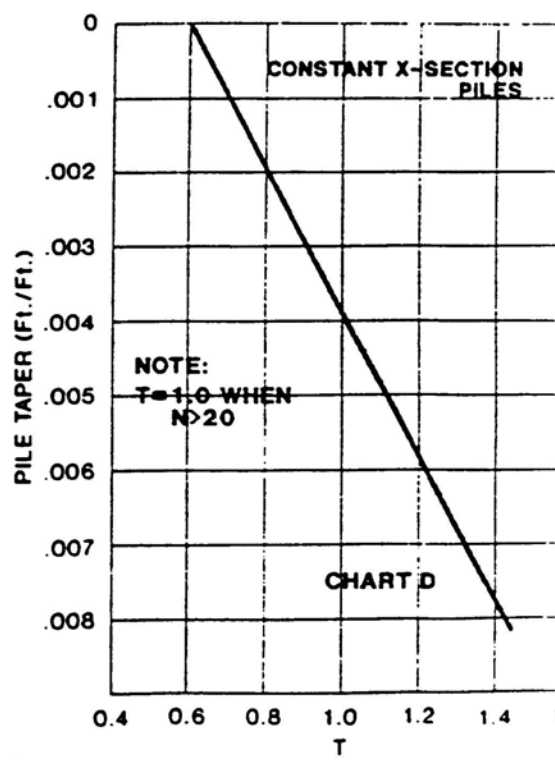
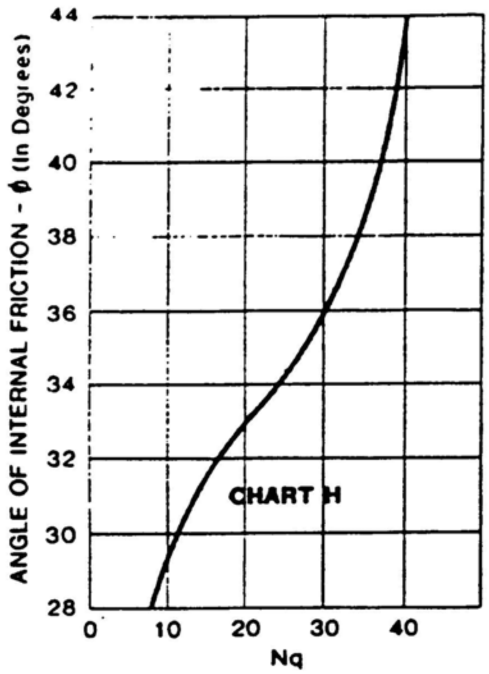
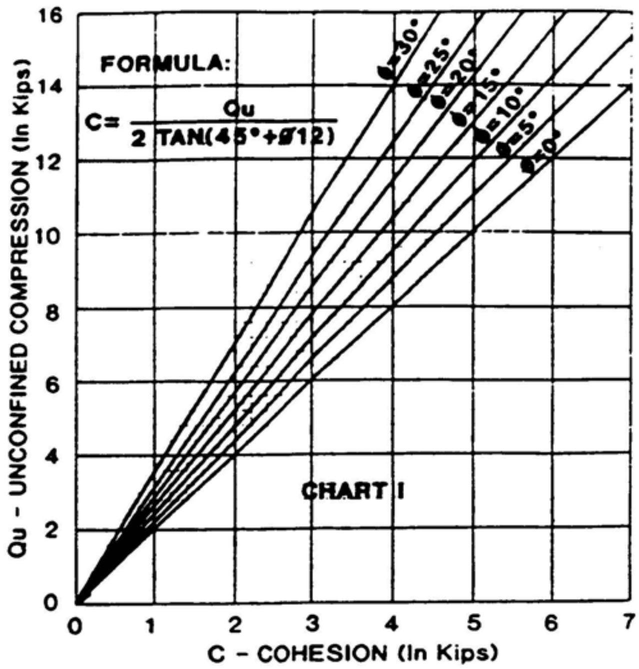
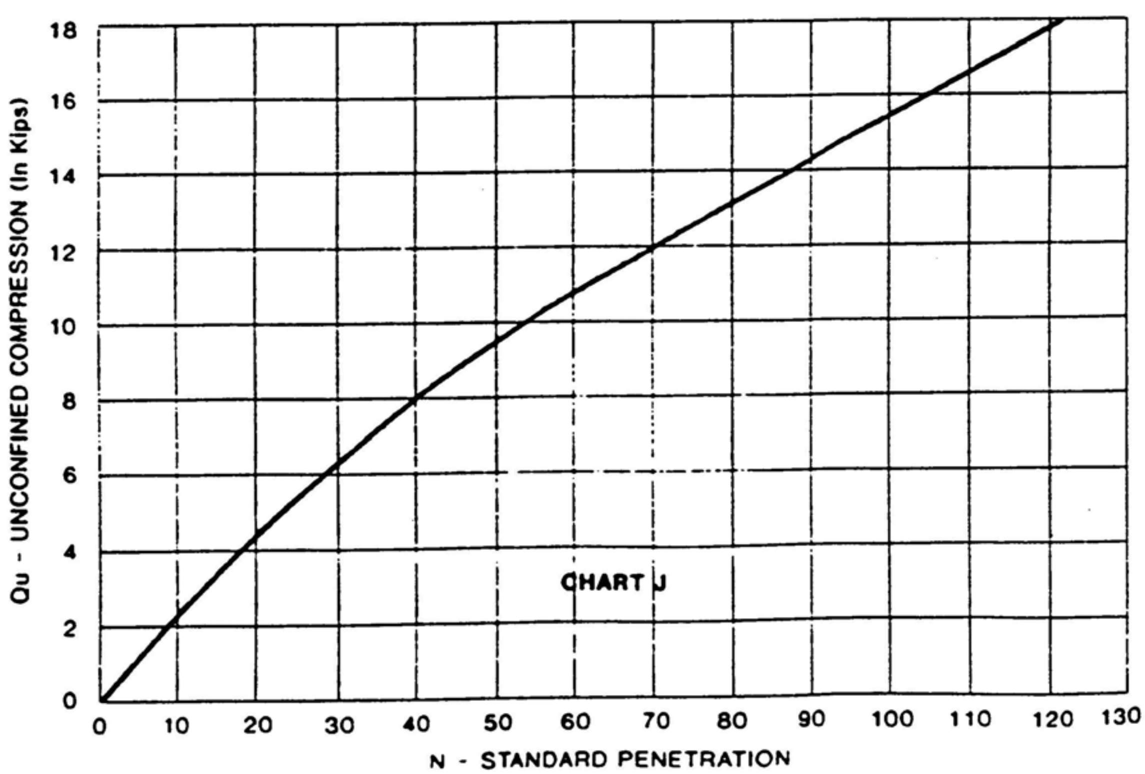
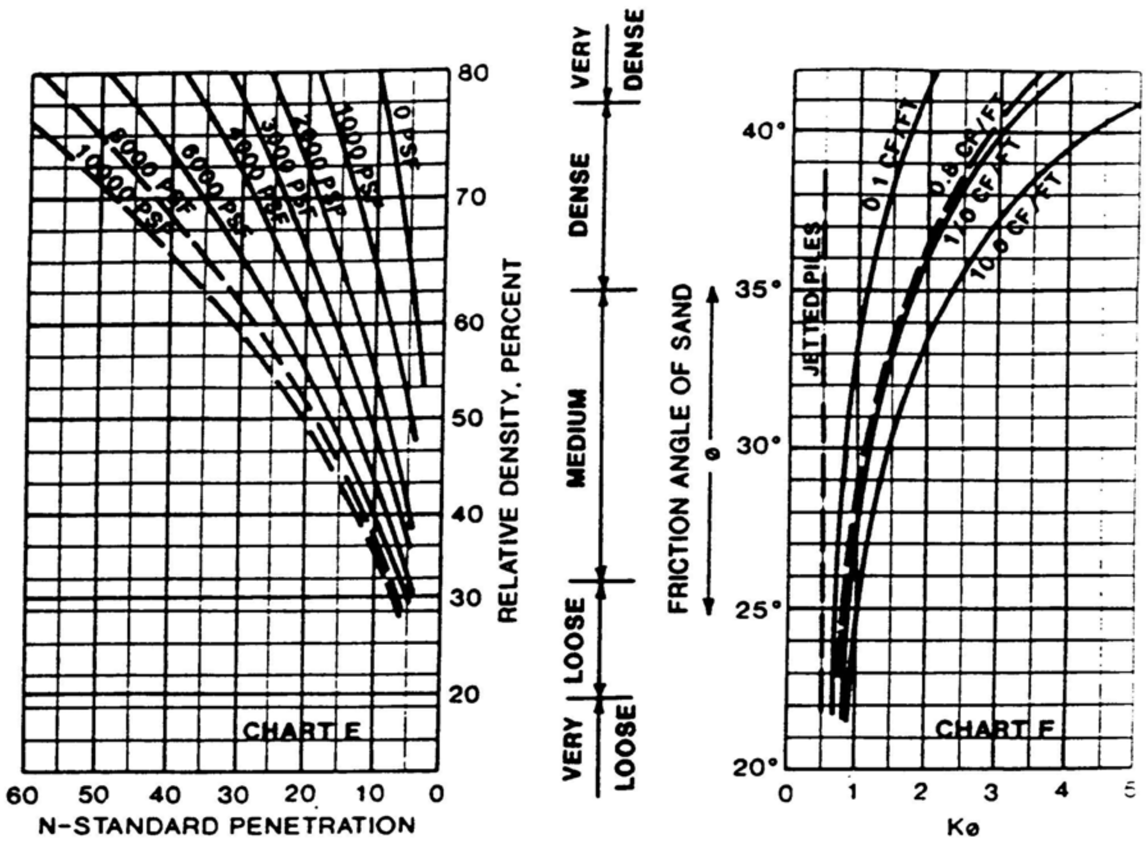


(LAKE AGASSIZ BASIN ONLY)


ANGLE OF INTERNAL FRICTION - ϕ (In Degrees)
CHART H
Nq


FORMULA:
$C = \frac{Qu}{2\ TAN(45° + ϕ/2)}$
ϕ=30°
ϕ=25°
ϕ=20°
ϕ=15°
ϕ=10°
ϕ=5°
ϕ=0°
Qu - UNCONFINED COMPRESSION (In Kips)
CHART I
C - COHESION (In Kips)


Qu - UNCONFINED COMPRESSION (In Kips)
CHART J
N - STANDARD PENETRATION



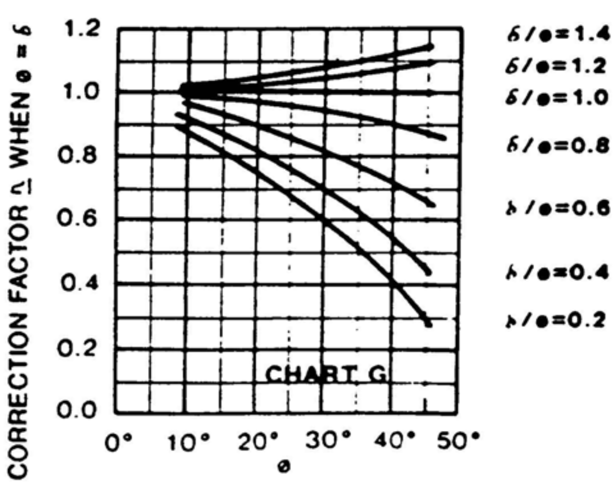
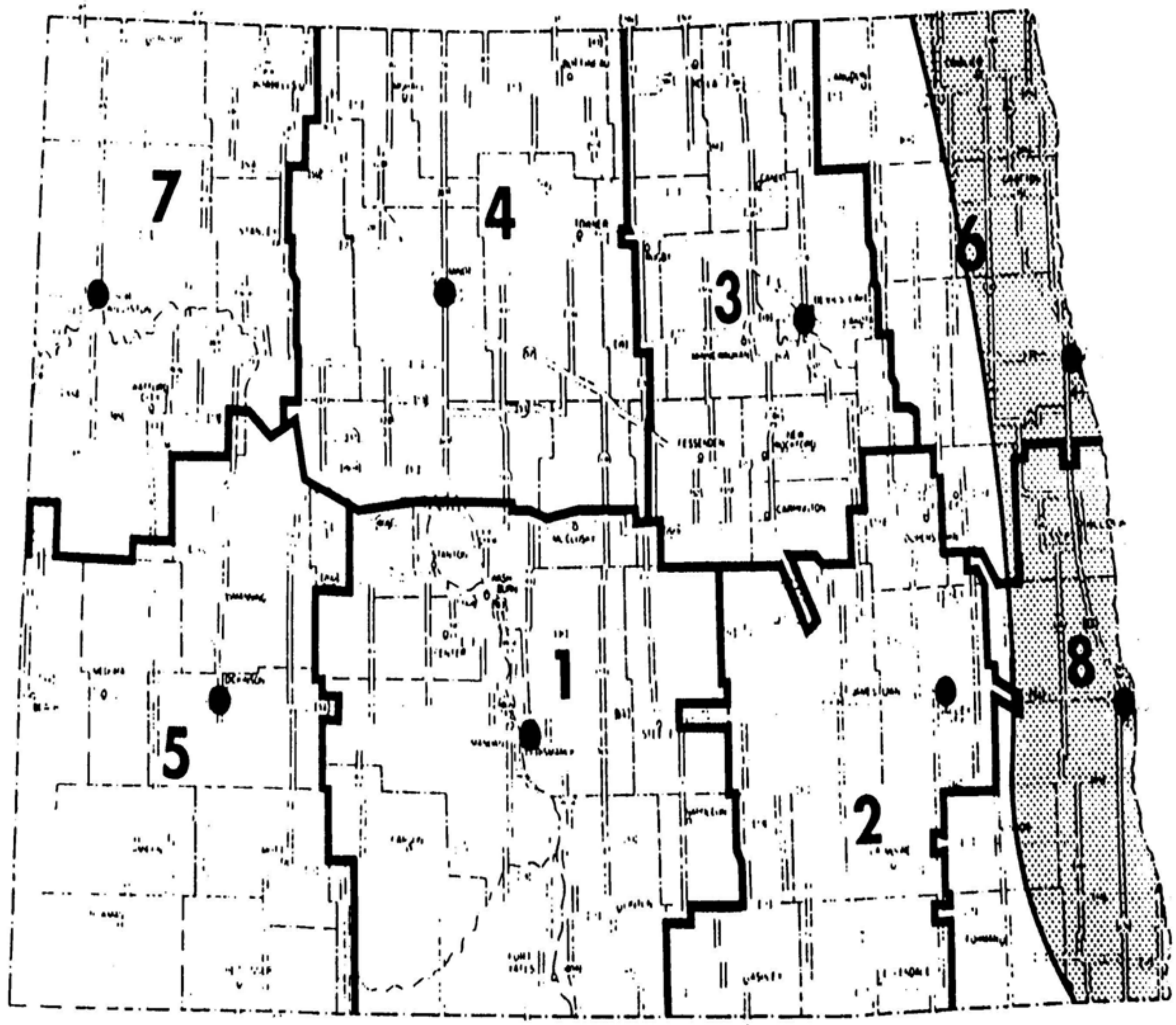


Figure 9. Friction factors for piles in granular soil: friction angle δ for sand on steel=18.5° (for piles with no appreciable taper).

assumed δ on wood=16°

NOTE: Charts E thru F taken from Michigan State Highway Department "Recommendations For Pile Design And Driving Practices."

North Dakota Department of Transportation



-Lake Agassiz Basin

District Boundaries

Appendix IV-06 B Installation of Utilities on Highway Structures

1. <u>General Features</u>

   a. Attachments of utility facilities to bridge structures should be avoided where it is reasonable to locate them elsewhere. However, where other locations prove to be difficult and unreasonably costly, attachment to a bridge structure will be considered, provided the attachment can be made without materially affecting the structure, the safety of traffic, the efficiency of maintenance of the structure, the efficiency of bridge inspections, its appearance, and provided the structure can support the additional load.

   b. Generally, utility installations must be attached to the bridge structure beneath the structure's floor, between the outer girders or beams or within a cell, and at an elevation above low superstructure steel or masonry.

   c. The location of utility facilities on a structure which will interfere with access to parts of the structure for painting or repair is prohibited. Manholes for utility access will not be permitted in the bridge deck.

   d. The utility installation on the bridge must be mounted so as not to reduce the vertical clearance above a river, stream, pavement, or top of rails. Utility attachments to the outside of bridges will not be permitted unless there is no reasonable alternative.

   e. Utility facilities must be firmly attached to the bridge structure and padded, where necessary, to eliminate noise and abrasion due to vibrations.

   f. Installation of utility facilities through the abutment or wingwall of an existing bridge is prohibited.

   g. In locations where a utility facility attached to a structure is carried beyond the back of the bridge abutment, the facility must curve or angle out to its proper alignment outside the roadbed area as quickly as is practical.

   h. Utility facilities may be attached to structures by hangers or roller assemblies suspended either from inserts in the underside of the bridge floor or from hanger rods clamped to a flange of a superstructure member. Bolting through the bridge floor or concrete beams is prohibited. Welding of attachments to steel members, or bolting through such members is prohibited. Where there is transverse bridge steel extending sufficiently from the underside of the bridge floor to provide adequate clearance, utility facilities may be installed on rollers or neoprene-padded saddles mounted atop such transverse members.

i. The design of a utility facility attached to a highway structure must include satisfactory provisions for lineal expansion and contraction due to temperature changes. Line bends or expansion couplings may be used for this purpose. Materials used for attaching a utility facility to the structure must be compatible with the structural material to eliminate the possibility of corrosion.

j. A utility facility and associated appurtenances attached to a highway structure must be painted when requested by the Department. The type and color of the paint will be approved by the district engineer.

k. Each proposed bridge attachment will be considered on its individual merits.

2. <u>New Bridge Structures</u>

a. Where the Department plans to construct a new bridge structure, the design of the structure will, upon request of a utility company, be reviewed for accommodation of existing or proposed utility installations consistent with the requirements set forth herein. The utility company may be required to reimburse the state for any additional costs associated with accommodation of the utility facility on the new structure.

b. Installation of a facility by a utility company on a new structure must be coordinated with the bridge construction so as not to interfere with the operations of the highway contractor.

3. <u>Pipelines</u>

a. Pipelines, except those requiring cathodic protection and those carrying natural gas, must be encased throughout the bridge and the casing must be carried beyond the back of the bridge abutment, and effectively opened or vented at each end. The casing pipe must be designed to withstand the same internal pressure as the carrier pipe. Pipeline with extra wall thickness may be permitted, in lieu of casing, by the Design Engineer if designed by the specifications approved by the U.S. Department of Transportation’s Hazardous Material Regulation Board.

b. The carrier pipe must be pressure tested before start-up in accordance with the latest edition of applicable industry codes, or appropriate regulations of an agency of the federal government.

c. Emergency shut-off valves must be installed on all pipeline attachments to a highway structure where such pipeline carries gas, liquid petroleum, or other hazardous materials under pressure. The shut-off valves should preferably be of automatic design and placed within an effective distance on each side of the structure, unless the pipeline is equipped with nearby shut-off valves or operates under effective control of automatic devices.

d. Pipelines carrying liquids subject to freezing must be protected to prevent the liquids from freezing.

4. Power and Communication Lines

a. Electric power and communication lines attached to a highway structure must be insulated from the structure, and carried in protective conduit or pipe throughout the bridge and to underground locations at each end of the structure. Exposed metallic conduit carrying electrical cables must be grounded separately from the structure.

b. Attachments for electric power and communication lines must provide sufficient clearance for convenience and safety during maintenance and repair of bridge structure or other utility installations on the bridge.

Appendix IV-06 C Pedestrian & Shared-Use Facilities on Structures

Highway Bridges that have a Pedestrian or Shared-use Path and Traffic Underneath

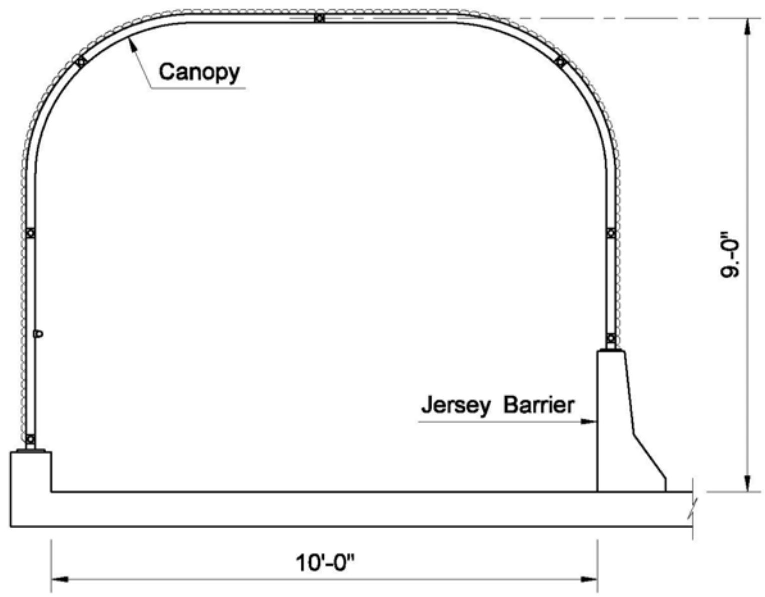


Figure 1A

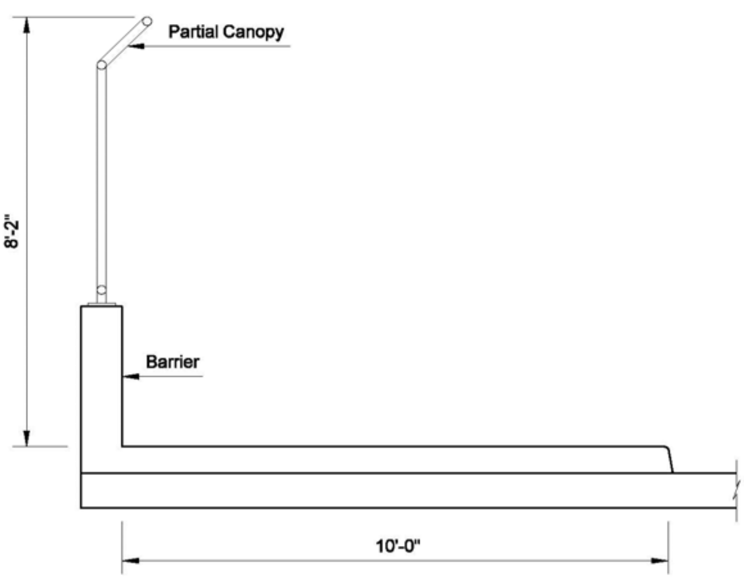
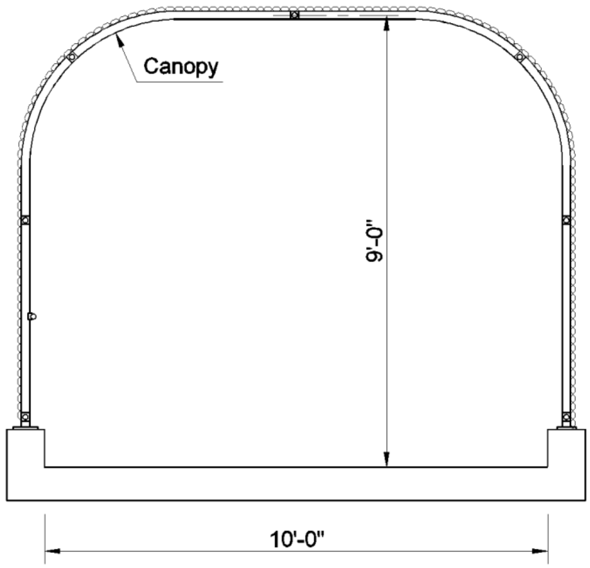
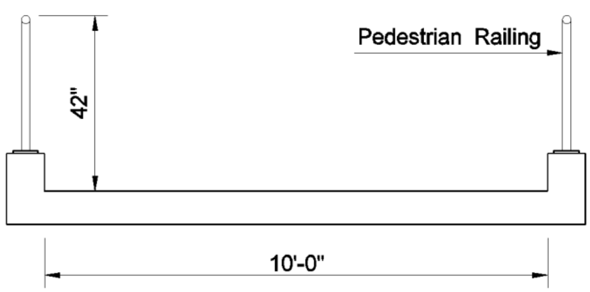


Figure 1B



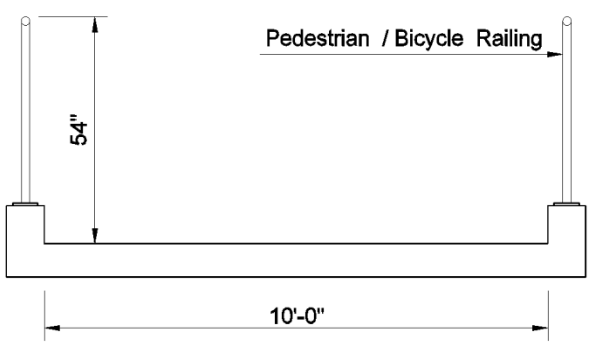
Any Pedestrian or Shared-use Bridge that has Traffic Underneath

Figure 2A



Pedestrian Bridge that has No Traffic Underneath

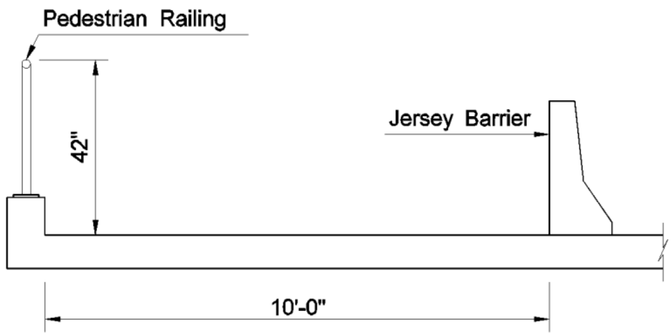
Figure 2B



Shared-use Bridge that has No Traffic Underneath

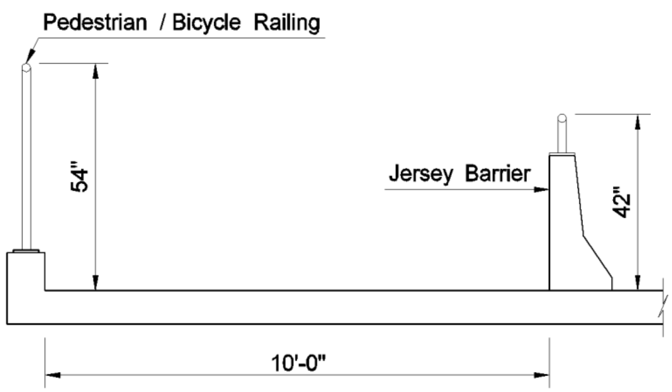
Figure 2C

Highway Bridges (High or Low Speed) with a Pedestrian or Shared-use Path with No Traffic Underneath



Pedestrian Sidewalk

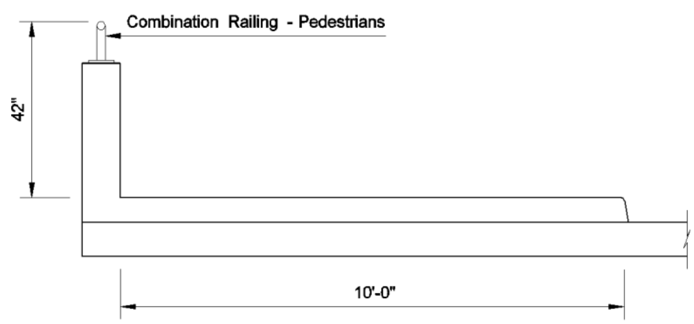
Figure 3A



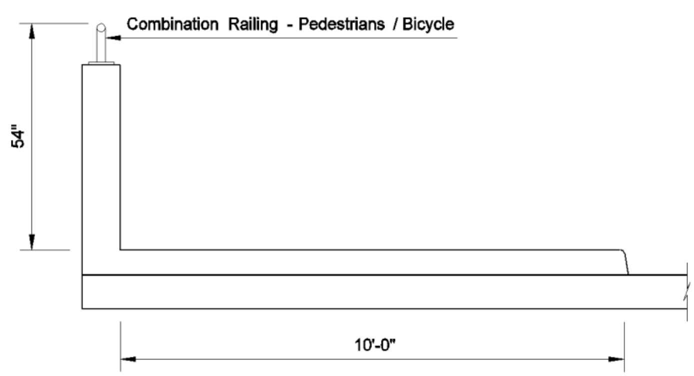
Shared-use Path

Figure 3B

Low Speed Highway Bridges with a Pedestrian Sidewalk or Shared-use Path and No Traffic Underneath



Pedestrian Sidewalk
Figure 4A



Multiuse Sidewalk
Figure 4B

Appendix IV-06 D Preliminary Engineering Meeting Agenda

Project:
Bridge Number:
Bridge Name:

A. Bridge Length:

B. Number of Spans:

C. Clear Roadway Requirements:

D. Beam/Girder Type & Spacing:

E. Embankment Endslope:

F. Abutment Type:

G. Pier Type:

H. Slope Protection:

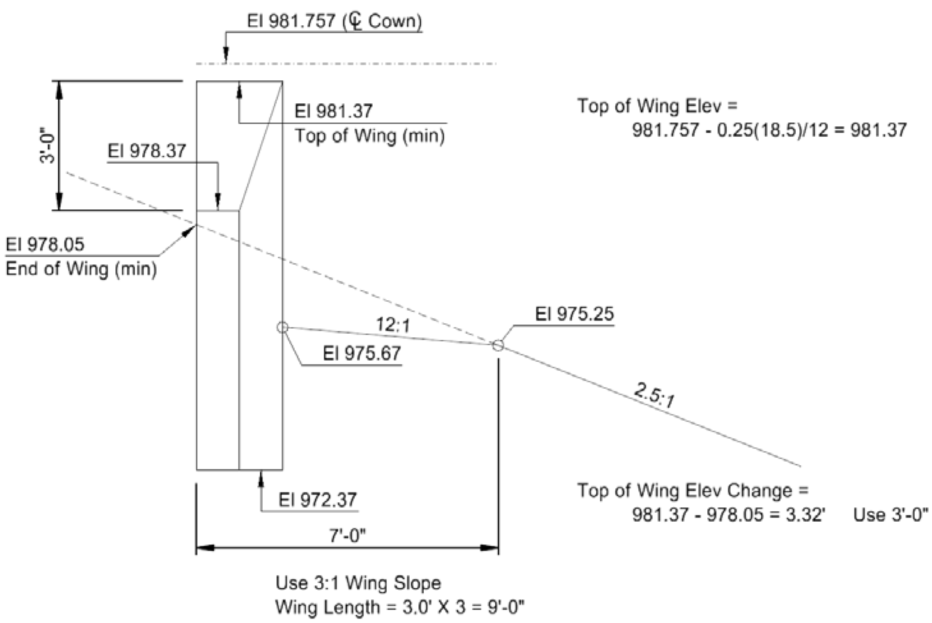
I. Approach Slabs:

J. Aesthetics:

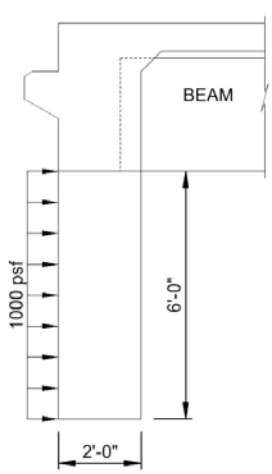
K. Other Criteria:

Appendix IV-06 E Integral Straight Abutment Design (Standard Specifications)

WING DIMENSIONS



WALL DESIGN (VERTICAL REINFORCING)



Design as a cantilever about bottom of beam.

$$Design\ Moment, M = \frac{1000\frac{lbs}{ft^2}(6.0ft)^2}{2} = 18{,}000\frac{ft-lbs}{ft}$$

Load Factor Design

Group I $\beta_E = 1.0$ Bridge Division Policy

$$M_u = 1.3\left(1.0 \times 18{,}000\frac{ft-lbs}{ft}\right) = 23{,}400\frac{ft-lbs}{ft}$$

Check capacity of #5's @ 12" spacing (min reinforcing).

AASHTO 8.16.3.2 $f'_c = 3{,}000psi$ $f_y = 60{,}000psi$ $b = 12in$

$$d = 24in - 2in - \frac{0.625in}{2} = 21.69in$$

$$A_s = 0.31in^2$$

$$a = \frac{0.31in^2\left(60000\frac{lbs}{in^2}\right)}{0.85\left(3000\frac{lbs}{in^2}\right)12in} = 0.61in$$

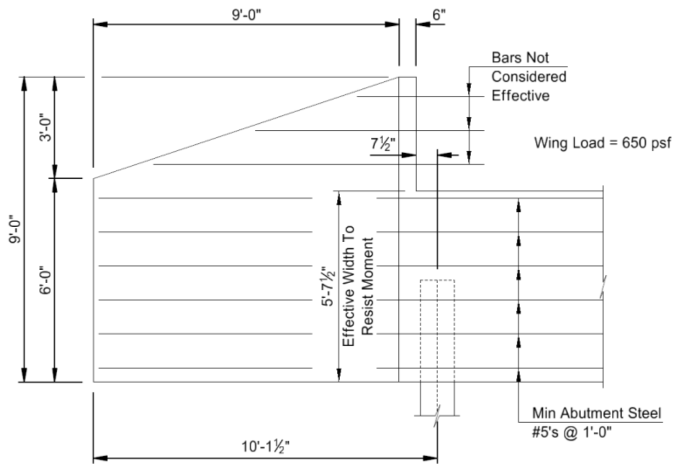
$$\varphi M_n = \varphi A_S f_y\left(d - \frac{a}{2}\right) = 0.9\,(0.31in^2)\,60000\frac{lbs}{in^2}\left(21.69in - \frac{0.61in}{2}\right) = 357,985in - lbs$$
$$= 29{,}832ft - lbs$$

$$M_u < \varphi M_n \ \therefore Use\ \#5's\ @\ 12"\ spacing\ for\ vertical\ reinforcing$$

Solve for maximum cantilever length (L) using #5's @ 12".

$$\varphi M_n = \frac{1.3\,(1.0)\,1000\frac{lbs}{ft^2}(L^2)}{2} = 29{,}832ft - lbs \ \rightarrow\ L = 6.77ft$$

WING DESIGN (HORIZONTAL REINFORCING)



When positioning pile in the abutment try to locate the outermost piles under the edge of the slab. The wing moments are calculated assuming the wing is cantilevering from the pile.

$$Bending\ Moment, M$$
$$= 650\frac{lbs}{ft^2}(5.625ft)\frac{(10.125ft)^2}{2} + 650\frac{lbs}{ft^2}(0.375ft)9.5ft\ (5.375ft)$$
$$+ 650\frac{lbs}{ft^2}(3.0ft)\frac{1}{2}\ (9.0ft)\ 4.125ft + 650\frac{lbs}{ft^2}(3.0ft)\ 0.5ft\ (0.875ft)$$
$$= 236{,}908ft - lbs$$

Group I $\quad M_u = 1.3\ (1.0\ \times 236908ft - lbs) = 307{,}980ft - lbs$

$b = 5' - 7\frac{1}{2}" = 67.5in$ $\quad d = 24in - 2in - 0.625in - \frac{0.625in}{2} = 21.06in$

$f'_c = 3{,}000psi$ $\quad f_y = 60{,}000psi$ $\quad \varphi = 0.9$

Use AASHTO equations 8-16 & 8-17.

$$\frac{M_u}{\varphi} = A_s\, f_y\, d - \frac{A_s^2\, f_y^2}{1.7\, f'_c\, b}$$

$$\frac{A_s^2\, f_y^2}{1.7\, f'_c\, b} - A_s\, f_y\, d + \frac{M_u}{\varphi} = 0$$

Solve for A_s using quadratic equation.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$A_s \geq \frac{\left[f_y\, d - \sqrt{\left(f_y\, d\right)^2 - \frac{4\, f_y^2\, M_u}{1.7\, f'_c\;\; b\, \varphi}}\right]}{2\,\left(\frac{f_y^2}{1.7\, f'_c\, b}\right)}$$

$$A_s \geq \frac{60ksi\ (21.06in) - \sqrt{[60ksi\ (21.06in)]^2 - \frac{4\ (60ksi)^2\ (307.980\ \times 12)ft - in}{1.7\ (3ksi)\ 67.5in\ (0.9)}}}{2\left(\frac{(60ksi)^2}{1.7\ (3ksi)\ 67.5in}\right)}$$

$$A_s \geq 3.34in^2$$

Area of additional steel required. $3.34 - 1.86 = 1.48in^2$

Add 4 - #6 bars. $A_s = 1.76in^2$

Add 4 - #6 bars front and back face. Bars that extend from the wing to the endwall are not considered effective.

Find capacity without using added bars.

$$a = \frac{1.86in^2\ (60000\frac{lbs}{in^2})}{0.85\ \left(3000\frac{lbs}{in^2}\right)\ 67.5in} = 0.65in$$

$$\varphi M_n = \varphi\ A_S\ f_y\ \left(d - \frac{a}{2}\right) = 0.9\ (1.86in^2)\ 60000\frac{lbs}{in^2}\ \left(21.06in - \frac{0.65in}{2}\right)$$
$$= 2{,}082{,}623in - lbs = 173{,}552ft - lbs$$

Solve for length from end of wing (L) where added bars are no longer needed using the average wing height.

$$\varphi M_n = \frac{1.3\ (1.0)\ 7.5ft\ \left(650\frac{lbs}{ft^2}\right) L^2}{2} = 173{,}552ft - lbs\ \rightarrow\ L = 7.40ft$$

Extend distance d = 21.06in. $7.40ft - \left(\frac{21.06}{12}\right)ft = 5.65ft$

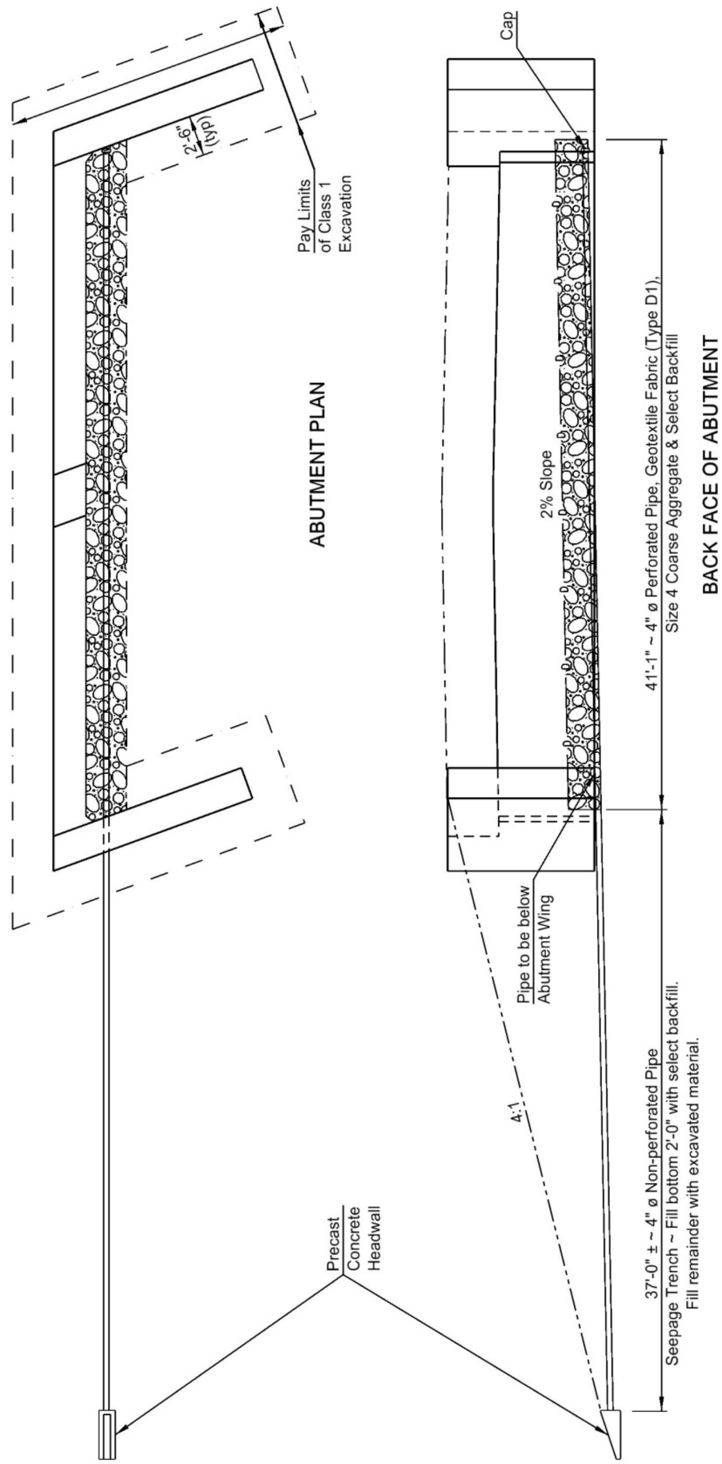
Start added #6's 5'-7" from end of wing.

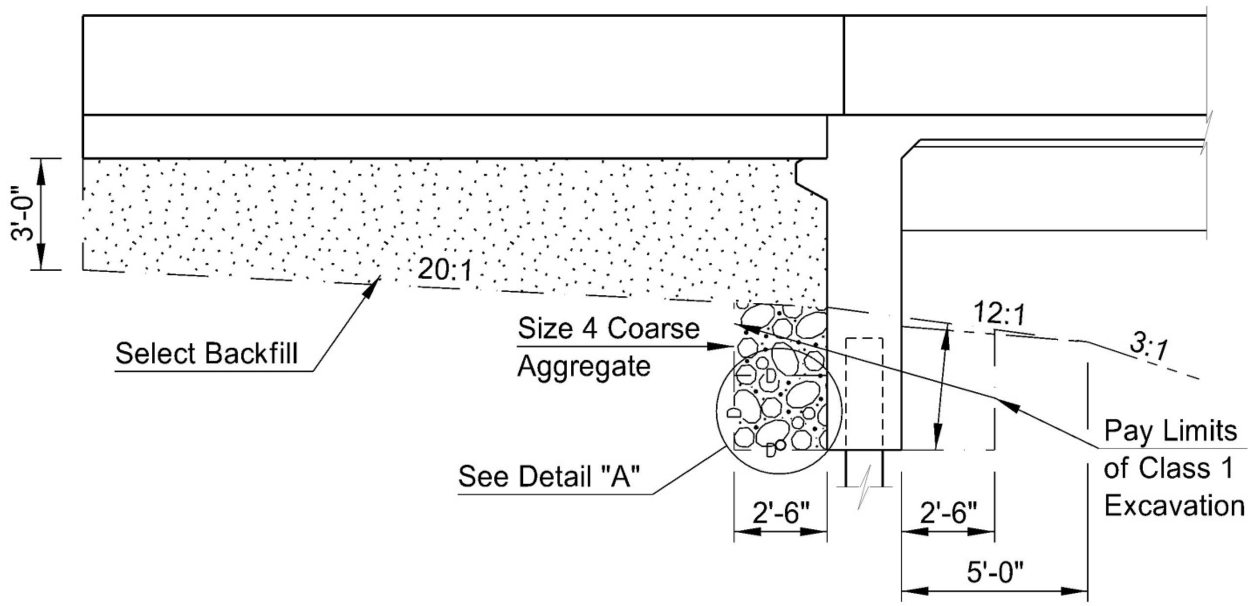
Assume zero moment at 0.2 point of pile span. For an 8'-0" pile span.

$$10.125ft - 5.5833ft + 0.2\ (8.0ft) + \left(\frac{21.06}{12}\right)ft = 7.90ft$$

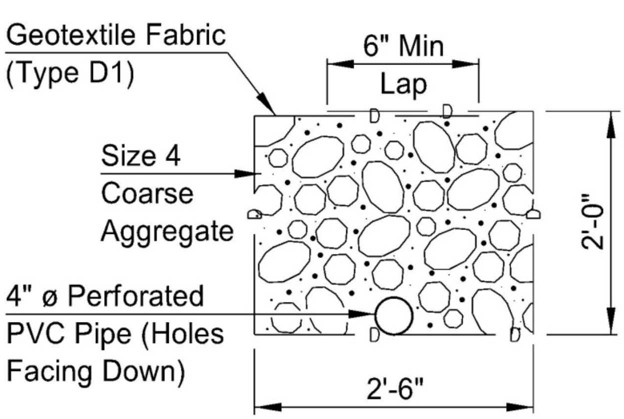
Length of added #6's = 7'-11"

Appendix IV-06 F Abutment Underdrain & Excavation Details





DETAIL AT ABUTMENT



DETAIL "A"

Appendix IV-04 G Checklist for Bridge Plans (SFN 17180)

CHECKLIST FOR BRIDGE PLANS
North Dakota Department of Transportation, Bridge
SFN 17180 (Rev. 6-2009)

Bridge Number	Project Number	Checked by	Date

Layout Sheet: (Items marked with * may appear on another sheet)

- ☐ 1. Bridge Code
- ☐ 2. Project No. Upper Right
- ☐ 3. North Arrow
- ☐ 4. Centerline Roadway Indicated
- ☐ 5. Begin and End Sta. and Elevations
- ☐ 6. Intermediate Sta. and Elevations
- ☐ 7. Roadway Width
- ☐ 8. Overall Length
- ☐ 9. Span Lengths
- ☐ 10. Fixed and Exp. Supports Indicated
- ☐ 11. Vertical Clearance
- ☐ 12. Horizontal Clearance
- ☐ 13. Structural Clearance Line
- ☐ 14. Test Piles Shown (if used)*
- ☐ 15. Boring Log Locations
- ☐ 16. Pile Loads*
- ☐ 17. Min. Pile Penetration*
- ☐ 18. Spread Footing Loads*
- ☐ 19. Bearing Plate Layout*
- ☐ 20. Berm Width
- ☐ 21. Berm Elev. (12 to 1)
- ☐ 22. Riprap - Slope Protection
- ☐ 23. Bottom of Footing Elev.
- ☐ 24. Substructure Units Numbered
- ☐ 25. Vertical Curve Data*
- ☐ 26. Benchmarks*
- ☐ 27. Screed Elevations (Each Girder)*
- ☐ 28. Original Ground Line
- ☐ 29. Piling Length Indicated
- ☐ 30. Correct Spec. Nos.*
- ☐ 31. List Special Provisions*
- ☐ 32. Enter Quantities*
- ☐ 33. Pounds of Structural Steel*
- ☐ 34. Enter Drwg. Nos.*
- ☐ 35. Design Loading (& Design Method)
- ☐ 36. Layout Titles
- ☐ 37. Project Number and Station
- ☐ 38. County
- ☐ 39. Drawing Number
- ☐ 40. Skew Indicated
- ☐ 41. Pay Quantity Limits*
- ☐ 42. Seepage Trench Shown
- ☐ 43. Approach Slab Shown
- ☐ 44. Datum Line
- ☐ 45. Bridge Cross Section*
- ☐ 46. Design Future Wearing Surface (F.W.S.)*
- ☐ 47. PE Stamp
- ☐ 48. List of Standards*
- ☐ 49. Hydraulic Data*

Note Sheet

- ☐ 1. Scope of Work
- ☐ 2. Miscellaneous Item Costs
- ☐ 3. Predrill thru Embankment
- ☐ 4. Embankment in Place Before Driving Pile
- ☐ 5. Reing. Steel Dimensions
- ☐ 6. Concrete Surface Finish
- ☐ 7. Cl. of Concrete and Type Coment
- ☐ 8. Approved Finishing Machine
- ☐ 9. Slope Protection
- ☐ 10. Riprap
- ☐ 11. General Pile Note
- ☐ 12. Removal of Existing Structure
- ☐ 13. Salvage and Disposal
- ☐ 14. Channel Excavation
- ☐ 15. Design Stresses (psi)
- ☐ 16. Classes of Excavation
- ☐ 17. Pile Hammer Size
- ☐ 18. Penetrating Water Repellent Trt. (optional)
- ☐ 19. Concrete Removal (Units and Quant.)
- ☐ 20. Anti-Graffiti
- ☐ 21. Bridge Approach Slabs
- ☐ 22. Deck Concrete Thickness Variations
- ☐ 23. Type of Structural Steel
- ☐ 24. Barrier Joint Spacing
- ☐ 25. Shop Drawing Requirements
- ☐ 26. Design Strengths
- ☐ 27. Design Method (Load Factor)

Other Detail Sheets

- ☐ 1. Detail Exp. Jt. Bevels
- ☐ 2. Field Riser Diagram
- ☐ 3. Riser Diagram Note
- ☐ 4. Blocking Diagram
- ☐ 5. Shop Camber Diagram
- ☐ 6. Concrete Placing Sequence
- ☐ 7. Field Bolt Placement
- ☐ 8. Drain Hole Location
- ☐ 9. Charpy V-Notch Test Req.

Appendix IV-06 H Interchange Clearance Diagram